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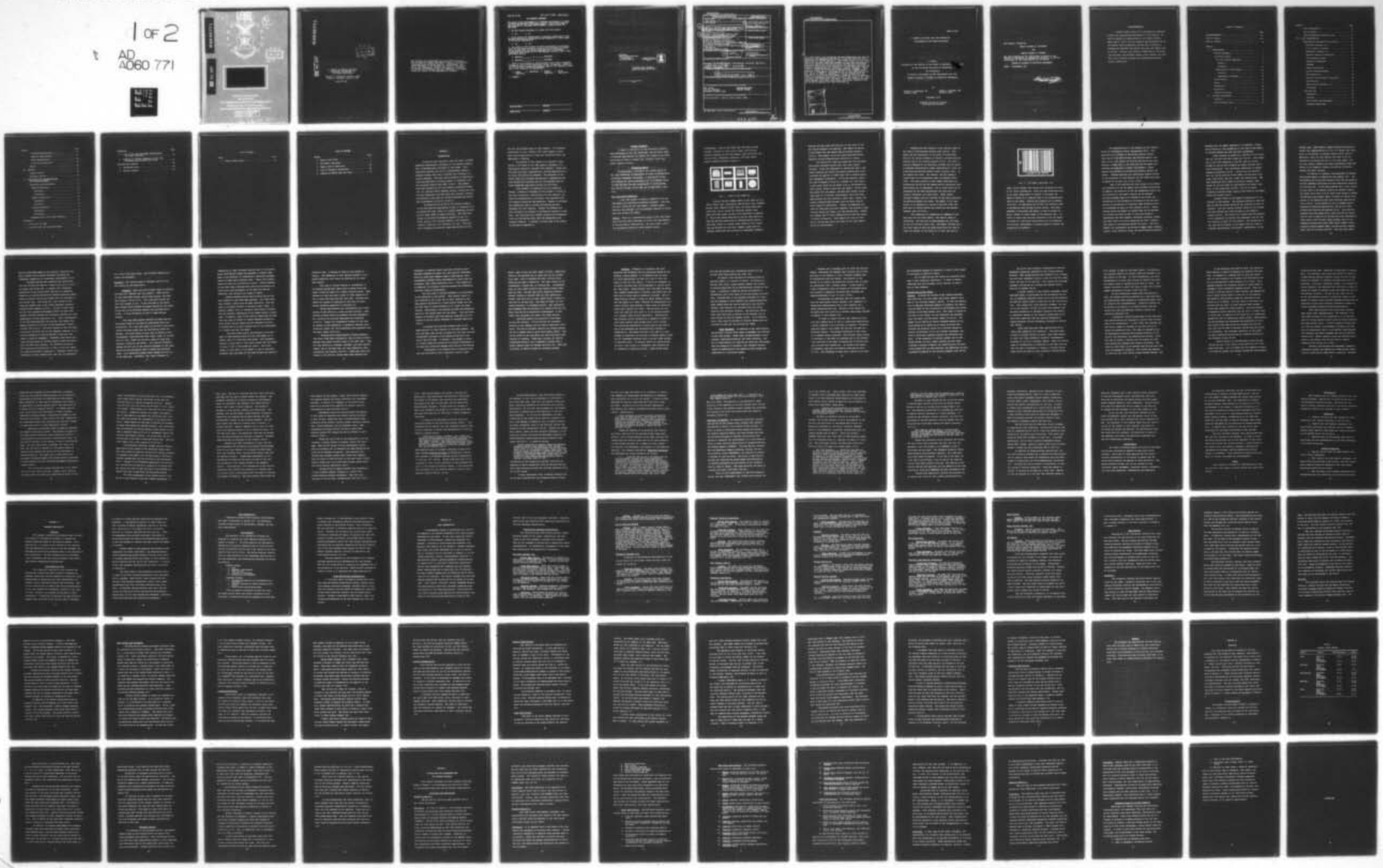

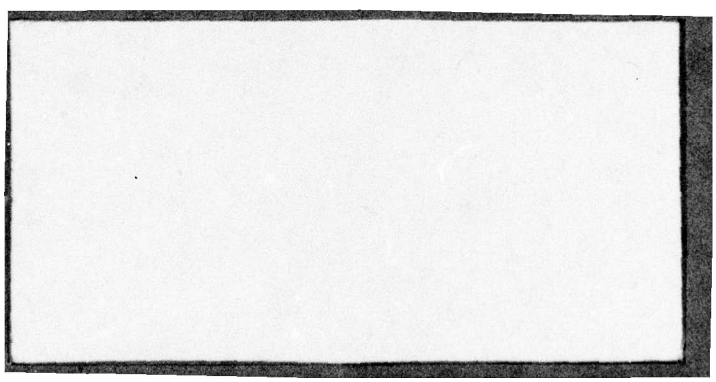

A SURVEY OF OPTICAL BAR CODE TECHNOLOGY APPLICABLE TO AIR FORCE ACTIVITIES

Michael B. Wilderman, Captain, USAF
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In recent years a new technology has been developing that has the potential for widespread application in the Air Force and other Department of Defense agencies. This thesis reports on the investigation of bar code technology amenable to Air Force applications. The study indicates that the military services and the Defense Logistics Agency have been directed by the Assistant Secretary of Defense (Installations and Logistics) to study Logistics Applications of Automated Marking and Reading Symbols (LOGMARS). This research effort was not directly related to the LOGMARS effort, but was an independent investigation of civilian applications of bar coding in order to determine if similar systems could be applied in an Air Force environment. Numerous civilian applications are presented along with a review of the types of bar coding equipment and symbologies available. The major finding was that there appears to be many areas where significant benefits could be gained by applying bar code technology.

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A SURVEY OF OPTICAL BAR CODE TECHNOLOGY APPLICABLE TO AIR FORCE ACTIVITIES

A Thesis

Presented to the Faculty of the School of Systems a[illegible]tics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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This thesis, written by

Captain Michael B. Wilderman

and

Captain Thomas D. Windham

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

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TABLE OF CONTENTS

Chapter | Page

Chapter		Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

During the last few years, there has been a rapidly expanding technological revolution in the grocery industry that is becoming more noticeable to the layman. This revolution involves the use of a standardized, machine-readable product code that is printed onto virtually all grocery packages. The code, which consists of alternating light and dark bars of varying widths, is referred to as the Universal Product Code (UPC) (21:11). This symbol, which was selected in 1973 over several candidate systems (21; 35), permits faster checkout service, reduces the rate of price mismarking, provides real-time inventory control, and provides a data base for various marketing and management requirements (21:38-39; 47:16-17).

Although the use of UPC in the grocery industry is the most familiar application of what is referred to as an optical bar code, there is a rapidly expanding utilization of these codes in other activities. Bar code technology is now being successfully applied by the U.S. Postal Service, the railroad industry, the automobile industry, hospitals, and libraries (33; 69). More specific information concerning these applications and the

UPC will be provided later in this chapter. It is perhaps significant to note, however, that there appears to have been limited application of this new technology within the Department of Defense.

The purpose of this thesis is to provide a broad survey of the types of bar code symbols, equipment, and applications currently available from industry. Based upon this data and other considerations, various applications to Air Force activities are proposed. The remainder of the thesis deals with problems encountered in implementing bar code systems and discusses why bar code systems have not found widespread application within the Air Force.

This document is organized into five chapters. Chapter I contains a statement of the problem, a review of the topic literature, justification for the research, the scope and delimitation of the effort, and concludes with the research objectives and questions. Chapter II provides the methodology used to collect and analyze the data necessary for this research. Chapter III presents the data collected, and Chapter IV provides an analysis of this data. The fifth and final chapter contains the recommendations and conclusions drawn from the presentation and analysis chapters. A glossary of terms used in the thesis is provided as Appendix A.

Problem Statement

In order to capitalize on the potentially significant advantages of this new technology, the Air Force needs to identify applications for optical bar coding in Air Force activities in order to reduce cost, manpower, save time, and/or improve accuracy.

Literature Review

At this point, a survey of the current status of bar code technology is appropriate in order to provide background for subsequent discussion. A description of bar code symbols and system components will be presented first, followed by some industry applications of these systems, and finally a review of what DOD has accomplished in this area.

Bar Code System Components

A bar code system is normally composed of the bar code symbol and associated processing equipment. This section will review the bar code symbol, including types, function, and problems, and the equipment required to print, scan, and process the symbol.

Symbols. There is a considerable number of bar code symbol types that have been developed to fulfill the requirements of various special applications. The size, style, color and information content of these symbols varies

considerably. Some of the codes that have been devised include, circular or "bull's eye" codes, half-circles, various groupings of bars and numbers, both horizontal and vertical bars, combination patterns, and other hybrid machine-readable markings (Figure 1).

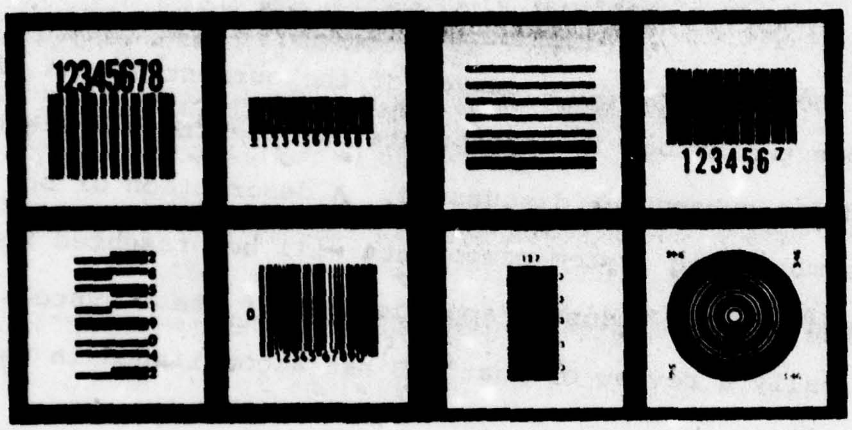

Fig. 1. Types of Bar Codes [4]

Some of the more common codes in use today are the "Two-of-Five" Code, Interleaved "Two-of-Five" Code, CODABAR, Decimal Code, "Three-of-Nine" Code, the Pulse Width Modulated Code, and of course the Universal Product Code. These and other codes are more fully described in Appendix B. One of the latest additions to the bar code family is from the National Association of Wholesale-Distributors. This code, which is a rather large (three to five inches long and minimum one inch tall) symbol, arose from the problems associated with printing on corrugated cardboard

surfaces and the rapid deterioration of that type of surface during shipment and handling. The symbol is similar to but larger than the symbol used on grocery products (52:16). This symbol, as do the others mentioned above, operates via the differentiated reflection of light.

All optical bar codes are based upon the principle that darker surfaces reflect less light than lighter surfaces. Using this phenomena in combination with a precisely designed and controlled pattern enables data to be collected and applied to useful work and to produce necessary management information. To be more specific, when a bar code is passed in front of a scanner (or vice versa), a light beam, which can be either from an incandescent or laser source, traces a path over the symbol. As the light beam moves over the symbol, the dark bars reflect little light back to a collector (photosensor) while the light space between the bars reflects a great deal. Hence, the scanner differentiates between light and dark lines by their degree of reflectance. Further, by measuring the width of these bars and their sequence, the scanner's logic circuits decode the symbol into the desired data. Different symbols use different combinations of bars and spaces to encode information. Some symbols use only the dark bars to encode data while the width of the light spaces are of no significance.

Probably the most familiar of all the bar codes in use today is the Universal Product Code (69:63). This symbol was the culmination of two years of coordinated study by the grocery industry to develop a standardized bar code for use in all grocery products (21:9). The code is normally composed of ten characters divided into two parts: an assigned identification number (manufacturer's code) and a manufacturer-selected product number (product code). No two symbols are alike. For example, the XYZ company's twelve-ounce can of applesauce might be numbered 62023-14231. The first portion of this number identifies the manufacturer as XYZ and the second portion identifies their twelve-ounce can of applesauce. For an eight-ounce can of applesauce by the same manufacturer the code would be slightly different, say 62023-14230. These "human-readable" numbers are also included on the label along with the machine-readable bar codes. The symbol itself (see Figure 2) is composed of a series of parallel light and dark bars of varying widths that constitute the machine-readable code (21:11-20).

Each character of information is composed of two dark bars and two light spaces. The overall shape is rectangular, and the size is approximately one inch high by one and one-half inches long. The symbol includes various other types of bars and guide marks which are used to alert the scanner of the direction of scan, the type of

Fig. 2. UPC Symbol (Enlarged) [41]

label, and to prevent the scanner from accepting too much or too little information. There are also provisions that can be made, where space is limited, to truncate the symbol's height or to suppress some of the nonsignificant zeros in the label. Chewing gum wrappers are an example (21:11-20). An additional set of bars are currently used on periodicals sold through grocery stores. This small addendum to the normal UPC symbol is used to encode the month, volume, or issue number of the magazine (56). In order to insure that the data contained in the UPC symbol is unique to a particular manufacturer and is compatible with scanner requirements, a certain degree of control and cooperation is required.

The standardization of UPC symbols is the responsibility of Distribution Codes, Incorporated (DCI). This organization is charged by the Uniform Grocery Product Code Council with administering the code distribution program (21:9). DCI issues and controls the use of the manufacturer's codes used in the first half of the symbol and oversees the suppliers of symbol film masters. These masters are provided to printers who actually produce the labels. Careless handling and insufficient quality control in the production of these masters and the labels have been a problem in the past (32; 35:22; 53:19).

Some of the problems that have arisen in the design and production of the UPC symbol have included the printing of symbols, the selection of bar and background colors, and the selection of the symbol location on the package. Printing problems seem to be focused on two areas; the variability of the surfaces to be printed on and the variability in the quality of resolution that different printing processes can apply to such surfaces (31:67). These factors affect the degree of success that can be achieved in printing the label so that it will scan properly. Impressions that have bubbles, scratches, blotches, breaks, and other forms of printing anomalies can have a significant impact on the scanning system (31:32-37). Bar code symbols can successfully be printed on paper stock, flexible plastic, metal surfaces, glass, and retroreflective material.

Assuming that the symbol impression is acceptable, another factor bearing on the scanability of the code is the degree of contrast between the bars and their background.

Label contrast is primarily a function of the colors used for the bars and their background (55:26). Oscar Mayer, one of the first companies to use UPC, made an initial mistake on one of their products by coding red bars over a yellow background. That particular combination is seldom scanned successfully (35:21). Colors that are satisfactory for the bar portion of the symbol include black, dark green, dark brown, and navy, royal, and medium blues. The best background color seems to be white; however, some shades of red and orange are satisfactory for black, navy blue, or dark green bars (55:26). The use of shiny aluminum to provide either light or dark areas of the symbol should be avoided (53:10).

Another factor in the symbol's scanability is its location on the package. The accepted practice to date has been to use the natural bottom of the container as much as possible. The term "natural bottom" refers to the surface that the customer will tend to place on the checkout counter (21:27). The intent is to insure that the operator of the checkstand can quickly and repeatedly find the correct surface to pass over the scanner. The scanability of the label may be reduced if the symbol lies too close to closures, perforations, score marks, indentations, or the

package edge. Additionally, symbols should be placed far enough away (approximately 0.10 to 0.15 inches) from other print on the package to prevent reading errors (53:12). Obviously, there are many factors that need to be considered in the design and use of a bar code symbol, and for that reason, industry has spent considerable money and effort on the research, design, and testing of various symbols and label surfaces.

In addition to industry, the Department of Defense has actively begun to examine bar code symbols (11). The anticipated use of bar code systems within DOD has prompted various proposals concerning the most appropriate symbology for military use. It has been proposed that a code similar to that used in the grocery industry be adopted; however, the symbol would need to be at least large enough to encode the National Stock Number (NSN) (thirteen to fifteen characters) to be compatible with most logistics applications (33:2; 54:17). Since letters as well as numbers may be required for many DOD applications, the use of a more flexible bar code may be required (33:2). One study has proposed that this symbol be at least thirty-nine characters so that in addition to the NSN and other alphanumeric codes used in the military supply systems (such as the shipment planning work sheet (SPW) serial number, Transportation Control Number (TCN), and the activity address code) could be included (60:129). This bar code, which

would be used where space is not critical, should be capable of being read in either direction and should be reasonably insensitive to orientation requirements (33:2).

Although the Army has conducted some evaluations (62) and the Navy has applied a type of bar code to one of its supply activities (64), it appears that widespread application of bar coding within the DOD will primarily depend on an on-going Services and Defense Logistics Agency study to evaluate the various sytems that are available at the current time. This study will look closely at the types and capabilities of bar coding equipment currently available from industry (62:131). As part of that study the Air Force Logistics Management Center at Gunter AFS, Alabama, has been charged with analyzing candidate bar code symbology(s) for DOD application (11). Their investigation so far has determined that the only bar code symbol that appears suitable for DOD use is the alphanumeric "Three-of-Nine" Code (61:iv). The final results of this and other portions of the study are not yet complete, however, so it would be premature to focus attention on only one code symbol or brand of equipment. Therefore, this thesis provides a broad survey of the many types of codes and equipment available from industry. As indicated previously, descriptions and illustrations of some of the more common bar codes are provided in Appendix B. Equipment varies considerably in style, capabilities, and cost, but generally

is of only a few basic types. The following section discusses that equipment.

Equipment. The various types of equipment used in a bar code system are discussed below.

Scanners. There are three general types of scanners available for "reading" bar code symbols. These devices are the fixed beam scanner, moving beam scanner, and hand-held scanner (4:8-18; 33:3). The fixed beam scanner was the first scanner in use. It was followed by the moving beam scanner which provided increased reliability and flexibility and by the hand-held scanner that provided portability. A brief discussion of each of these devices follows.

The fixed beam scanner obtained its name from the stationary nature of its beam and associated optics and electronics. For a bar code symbol to be read it must move through the beam rather than the beam moving across the package. The light source of this type of scanner can be incandescent, light emitting diode (LED), laser, or flourescent (3; 4:8). There are two basic types of fixed beam scanners, reflective and reflex. The primary difference between the two lies in the relative alignment of the light source and the photosensor used to gather the reflected light. In a reflective scanner these elements do not lie on the same axis. Therefore, this type of scanner is

insensitive to light reflected directly back to the source. Since retroflective labels are designed to reflect light back in the direction of illumination, reflective scanners would not sense this reflected light. Hence, this scanner cannot be used with retroflective labels. Reflex scanners, on the other hand, overcome this limitation by placing the light source and photosensor on the same axis and can, therefore, read virtually all types of labels.

Reflex scanners provide good accuracy and are the most flexible of the fixed beam scanners. All fixed scanners, however, suffer from the same limitation. Only one pass is available in which to correctly read a label. A scratch, smudge, void, or overprint could easily interfere with the scanner's perception of the symbol during a single pass. In general, then, better quality labels must be used with this type of scanner to insure adequate reliability. Since higher quality labels are more expensive (4:8-10), an alternative is to use a scanner that is not constrained to a single pass over the symbol.

The moving beam scanner was designed to provide a means to make multiple scans of a bar code symbol as it passed, even at a relatively high speed. This equipment employs a flying spot of light which passes over the symbol at rates of 180 to 600 passes per second. The actual number of times that a given symbol is read is obviously dependent upon the speed of the label through the scanner's

effective view. A minimum of three or four passes is typical. The redundancy of this approach permits a validating capability that cannot be achieved by the fixed beam scanner.

This type of scanner employs an incandescent or low powered helium-neon laser which is moved across the symbol surface by means of a rapidly rotating mirror. Most scanners of this type have a depth of field capability of two to three feet deep and four feet high. Although most labels are scanned at distances of less than two feet, greater distance capability is available (3).

Moving beam scanners can successfully scan a wide variety of bar colors on various printing surfaces. Manufacturer printed labels are probably the most dependable, but virtually all printing techniques are acceptable (4:16-17). Though the incandescent variety of this type of scanner is less expensive, it generally requires retroreflective labels that are considerably more expensive than the paper labels (32:16-17).

Although moving beam scanners are more expensive than their fixed beam counterparts, they are more reliable because they permit multiple scans of the same label. They are less sensitive to damaged, degraded, and lower quality labels, and at the same time, are less affected by label orientation and location (4:16-17). Based upon tests conducted by the military, moving beam laser scanners were

successful in scanning labels that were covered by polyethelene wrappings of three, six, and eight mil thickness, which are those most commonly used in Army depots, while incandescent scanners using retroreflective labels were not successful under these conditions (33:3). This capability is essential for military logistics systems that frequently wrap many items in polyethelene.

The last type of scanning equipment to be discussed is the hand-held or pen scanner. This scanner, which is also referred to as a light pen or wand, operates on the same general principles as a fixed scanner except that the pen must come in close proximity to (or touch) the label surface. Additionally, the operator provides the mechanical motion of the scanner beam over the symbol. This particular scanner is normally used when scanning items that are stationary or are not easily adaptable to conveyor operations (32:17).

A problem with hand-held scanners that is not characteristic of other scanners is the human element. The rate and angle that the pen is moved over the label can have considerable influence on the scanner's ability to correctly read the label. In general, scan speeds of three to fifteen inches per second and an angular displacement of not more than forty-five degrees from vertical are desired.

Differences in the capabilities of hand-held scanners are functions of their resolution, type of light

source, type of tip, and their depth of field. Resolution refers to the smallest bar or space that can be successfully read. This is probably the most critical factor affecting the wand's capability. The light source can be incandescent, visible LED, or infrared LED. Incandescent types are more shock sensitive and require greater power than the LEDs. The bar code colors generally determine whether visible or infrared LEDs are most appropriate. Scanner tips vary with the most common being a saphire or ruby ball or an open cone. The depth of field, as indicated previously, is extremely limited. Most manufacturers recommend that the surface be in contact with the tip. While this may be an operational disadvantage, it does permit very low-power and longer life light sources.

Hand-held readers are basically of two types, on-line and portable. On-line devices are connected directly to the computer and are used at stationary locations. Off-line or portable versions are battery powered and use a cassete tape or solid state memory system. Data can be stored on the tape while the user moves about from location to location. After use, the data can then be transferred directly into a computer or placed onto a larger computer tape for storage (4:13-15; 12). This type of scanner is ideally suited for inventory surveys.

Printers. Although it is possible that most materials and containers will be previously marked by the producer (source marked), it is possible that for many Air Force applications the user will need to print and apply his own bar code labels. A variety of equipment is currently available that can be employed to locally print bar code labels. These printers vary from desk top models that resemble typewriters to conveyor line models that are more akin to those used by industrial printers. Most of these printers utilize a roller or impact system to apply the code symbol to a label, although one manufacturer provides a printer that produces a label using an electronic system and a special dry toner. Some printers not only print the label but also apply it to the desired surface as it passes (label printer applicator). Additionally, many printers can be connected to a computer in order to print data directly from storage files (32:6; 62:128). This particular application is being used by the Army at one of its packaging and containerization centers in Pennsylvania. The system utilizes a bar code on a lead package to stimulate the printing of address labels on that and all subsequent packages until a new bar coded package is detected (32:6). To produce labels for random weight articles, such as meat or vegetables, some printers can be connected to electronic scales. These scales weigh

the item and provide this information directly to the printer which then produces the label (70).

In general, most printers can produce single or multiple labels in a variety of styles. In addition to the bar code itself, human-readable numbers and letters in varying quantities can be simultaneously printed on the label. A sequential numbering system (incremental or decremental) and a wide range of printing speeds are available. Although most of the printers available for local use are designed to print symbols onto pressure-sensitive paper labels which can then be applied to the required surface, some printers are available that will print directly onto container surfaces. One particular wholesaler uses this type of printer on his conveyor line to mark cartons as they are sealed (65:39). It is apparent that a wide range of printers of varying capabilities are available to the user for printing bar codes.

Other Equipment. In addition to bar code scanners and printers, various other types of equipment are involved in bar code systems. These items include decoders, multiplexers, computers/processors, and label verifiers. Not all of these devices are required for every bar code system. With the exception of decoders, they represent various levels of sophistication and capability that extend the usefulness of a particular system.

Decoders are a necessary part of every bar scanning system. Frequently the decoder logic circuits are an integral part of the scanner; if not, a decoder assembly must be incorporated into the system. The function of the decoder is to convert the electrical signals from the scanner photosensor into a useable format. A wide range of output transmission rates and formats are available which will provide a compatible interface with virtually any computer/processor in use (2; 4:14; 13:56).

Multiplexers are available that will permit more than one input/output device (scanner, CRT, keyboard) to communicate simultaneously with a host computer via a single communications link. Devices of this nature are available that will allow up to sixteen input/output devices to operate in this fashion (13).

In order to insure that bar code labels are accurate and readable prior to use in a particular application, a device referred to as a verifier is required. Verifiers generally employ a pen reader and function the same as a hand-held scanner. The primary difference is that there is no useable output generated. The verifier simply checks to determine if the label is scannable and if the information contained in the label is appropriate (a digital display provides this capability). An audible tone signals a successful read while its absence indicates an error (2; 26). The advantage of using such a device is to avoid

the unnecessary expense of accepting or using a large number of inaccurate or defective labels.

All of these devices and others are currently being used in many industrial operations. In order to better understand how this equipment can be applied, we need to look at some examples.

Applications of Bar Coding

Industry. Although the concept of bar coding originated some years ago, its first major application seems to have been in the railroad industry (69:66). In 1967 the Association of American Railroads adopted an automatic car identification label to aid in monitoring the movement and current location of its many freight cars. This label is posted on the side of the freight car and identifies the equipment type, the owner, and the serial number of the car. The symbol can be read by an optical roadside scanner as the train passes by at speeds up to eighty miles per hour. Although the potential exists for a national system to monitor the movement of all rail freight containers, the lack of sufficient roadside scanners has inhibited this goal. Of the estimated 1.8 million freight cars in the United States, all but a small fraction are bar coded. Although a national automatic car identification and monitoring system has not been realized, the technology has been successfully applied at the railroad terminal area (69:66).

The first fully automatic transportation terminal management system was installed by the Illinois Central Railroad. This system monitors the movement of all freight cars and their piggyback trailers, which are also bar coded, within the area of the terminal. This system has increased equipment utilization by 9 percent and reduced overall costs by 30 percent (69:66).

A system, similar to the terminal management system described above, is envisioned for the processing and control of shipboard containers which are on and off-loaded by the American Export Lines at their Port of New York facilities. This system will track container movement into and out of the terminal, as well as within the terminal, and provides information on equipment inventory and control. An additional benefit of the scanning system might be to alert work crews when they are handling dangerous or fragile material via the information contained in the bar code (69:66).

There have been many other applications of bar coding both commercial and industrial. The Buick Motor Division of General Motors is using a laser beam scanner to read a bar code attached to automatic transmissions produced at its Flint, Michigan complex. There are several types of transmissions in production at the same time and this has made it necessary to develop a tracking system. Coded labels are used to carry production identification,

and a scanner is used to read these labels. A production-line operator selects the correct label and attaches it to the outside of the case. To avoid mislabeling, the first transmission of a given type carries an identity tag which the labeler reads to determine which label to apply. The labeler continues to apply that type of label until another tagged transmission arrives on the line (23).

As the transmission travels down the production line, the scanner monitors production on a real-time basis and continuously sends signals to a decoder/processor which is linked to two teletypewriters. Production figures can be printed on an hourly or as required basis, and the figures are used by production, material control and accounting personnel (23).

A production control system based on bar code scanning identification and tracking of circuit cards is being used by one manufacturer. A vinyl label that contains the card serial number is attached to the bare card as it enters the production line. The label is scanned during the manufacturing process which enables tracking of the circuit card throughout the manufacturing process. After the card is tested, a history file is created for each card showing any problems that require correcting. The vinyl bar code label is not removed from the card until the card is packaged for shipping. This allows the computer to track the card from initial stages through shipment (28).

At the wholesale distribution level, bar coding is being applied to improve procedures for physical distribution. An example of a company that is using bar coding (UPC, in this instance) for inventory and distribution control is the Manhattan Coffee Company of St. Louis. This company produces four different grinds of coffee which is packaged in four differently labeled cartons. After converting to UPC bar coding on their cartons, the company now uses a single carton stock to cover all of its products. The specific identification codes are imprinted on the carton as it is sealed. All four sides of the carton are printed with the label to insure greater label accessibility when needed for identification. The Plant Manager of Manhattan Coffee indicates that the use of a single type of carton that is labeled on four sides as it is sealed has reduced the cost of maintaining carton stocks. Additionally, the new technique has eliminated the possibility of leftover carton stock when grinds are dropped from the product line and the need to preprint cartons when new grinds are introduced. The increased visibility of the labels has also simplified palletizing and inventory handling of the different grinds (65:39).

Another benefit at the distributor level derived through the use of bar coding is the generation of a computer data base. Data is loaded into the computer by means of an optical scanner that gathers information from products

carrying the bar code. This data is then used in numerous ways. For instance, item counts and records of sales are tracked against desired inventory levels and when reorder points are reached, an automatic purchase order would be generated. Printouts, indicating trends in the movement of various products, are generated from this data in order to reduce the chance of obsolete items from gathering dust on the shelves (22:55-56). As you can see, then, the use of bar code systems can have a significant impact on the degree of product control through improved handling and the generation of pertinent inventory information needed for timely management monitoring and decision making.

Other applications of bar coding have included some rather novel implementations. For instance, a bar code label attached to the windshield on a car has been used to activate parking control gates for staff personnel and other regular users. A similar system is being used at a few toll booths on expressways to permit cars that carry an appropriate label to use express lanes equipped with scanners that sense customers who will be charged a reduced rate. Boston commuter trains are similarly monitored in this fashion and the data used to improve scheduling and routing (25; 69:63).

National Cash Register has developed a hospital information system that employs bar coded patient identification cards and bar coded service catalogs. Services

prescribed for a patient can be entered into a computer along with the patient's identification and the operator's identification by means of a hand-held bar code reader. This information is then used for scheduling and routing of medication, including dosage, day or time medication is to begin, and the frequency (69:65). In another application, x-ray folders are monitored in a Boston research hospital by encoding patient identification numbers in bar code onto the folders. These folders are then "logged out" by a hand-held scanner when they leave an area and "logged in" when they arrive at their destination (69:65).

Libraries are using bar codes to speed up checkouts and improve circulation control. The systems are based on bar coded pressure sensitive labels which are placed on loan materials and the borrower's identification card. At the time of checkout, a pen scanner is used to read the bar code. The data read enters a processor unit and at the same time the book is checked out, the patron number is checked to see whether the patron has any delinquent or reserved material. The input data is then used by the processor to produce reserve and overdue notices, printouts of items that are on loan, and other management information reports (69:66).

One of the most unusual applications of bar coding has been in the cotton business. Labels, which identify the field where the cotton was picked and the owner of that

field, are attached to each cotton bale as it is produced. Other labels which reflect the weight of the bale are affixed later at a central processing facility. Samples from each bale are then taken and attached to their respective labels. These samples are then used for both grading and buying. Prospective buyers can inspect the samples, and if they desire to purchase that particular bale, scan the label and provide the information to the market officials. These labels are also used to monitor the movement of bales from production through delivery. The information that is collected at various stages of this system is also used to generate reports to fulfill management control and analysis requirements (69:68). As can be seen, the bar code concept can be used in many and varied ways. The only limit seems to be in the ingenuity of the user.

As previously indicated, perhaps the most familiar application of bar coding is the Universal Product Code. This code, which is found on virtually all grocery products, is intended to be used in the various types of electronic checkout systems that are now arriving on the supermarket front. Because of its widespread application and familiarity, the UPC will be used as an example to illustrate how the typical bar code is used and some of the problems and impacts that have arisen from this particular system.

The first supermarket in the United States to use the UPC at the checkout stand was a Marsh supermarket in

Troy, Ohio. The system installed (NCR 255) was of the basic type that will be used in stores across the country. The equipment consists of an optical scanner in the checkout stand, an electronic cash register with remote display device, and a small in-store computer. The system is designed to work quickly, quietly, and efficiently. The package, with the UPC symbol placed downward, is manually passed over the scanning device which decodes the label and provides a signal to the in-store computer. The computer checks the label for accuracy and if correct, it accepts the data. Should a package fail to scan, an alarm alerts the checkout person to try to rescan the item. If the item fails again, the appropriate code must be entered into the system through the register's keyboard. Noncoded items must also be processed in this fashion (22:23).

Assuming the label information is good, the computer processes the information and locates the programmed price of the item, whether it is taxable and food stampable, the inventory level, and the dollar amount sold over the checkout counter. Appropriate adjustments to this information are made and the price and name of the item are transmited to the readout screen at the checkout counter. Simultaneously, this information is fed into the electronic cash register for printing on a receipt tape. An internal tally is maintained until the order is totalled and payment is tendered. The cash register then prints the

total amount of the receipt. Later, the in-store computer can generate product and sales information for management analysis. A link-up to a computer in the chain's headquarters to provide daily reports for central reporting requirements is also available (36:23).

Supermarket chains are solidly behind UPC because it will speed up checkouts and reduce lines by one-third or more (21:38), reduce the cost of price-marking items, eliminate "price checks," provide instant inventory information, reduce pilferage, and cut warehouse costs. Many supermarket officials believe the day is coming when products without UPC labels will not be allowed on their shelves (59:51).

Though the use of UPC in the supermarket is on the increase, a certain degree of consumer concern has developed. When the UPC system is fully implemented, pricemarks on packages will be replaced with shelf-marked prices which can be changed as required. This situation has annoyed some consumer groups which claims that shoppers have the right to read the price on the item itself (36:24). Several states and a few cities have already passed mandatory price marking legislation (20:3).

Holiday Foods of Seattle handled the introduction of the automated checkout counters in a manner that created minimum customer resistance. They were very thorough in telling their customers what they were going

to do. Three months before the checkout counters were operational, they distributed "bag stuffers," advertised the change in the papers, and contacted the news media. Some people that were curious about the new system have become steady customers. Holiday Foods was pleased to learn that customers that moved ten to fifteen miles from the store are going out of their way to remain customers (45:29-30).

A study by Food Marketing Institute found customers more aware of new electronic systems (68:56). This awareness and the feeling that the automated checkout stand is more convenient is making the implementation of the new checkout counters easier.

> Yankelovich, Skelly, and White, Inc., which conducts an on-going examination of trends affecting food distribution, surveyed by telephone 1,039 persons (80% women, 20% men). When this representative group was asked to rate [scanner] technology in banks, retail stores, and supermarkets, 41% found the systems helpful, 15% not helpful [68:5].

This positive trend in consumer acceptance is one of the major reasons Progressive Grocer is predicting a 113 percent increase in automated checkout counter installations in 1978 over 1977 (68:56). Though sufficient data is not available to make a final prediction on how consumers will react to the automated checkout counter, it has reasonably been estimated that the retailer stands to accrue a substantial economic benefit (21:38).

As mentioned earlier, with item prices stored in the computer, it will not be necessary to individually price mark each item. This will also prevent items from being incorrectly marked by an inattentive stock person. Additionally, the training time necessary for the checker operation is reduced due to the simplicity of the automated equipment. In the area of management, the data accumulated by the system can be used for inventory control, item movement information, and to generate reports and other information vital to the efficient control and direction of the organization (21:39). Besides the management reports, faster and more accurate information is provided the retailer and marketing department regarding the effectiveness of advertising and sales promotion techniques (47:16-17). In terms of savings:

> Studies supported by leading chains and equipment companies indicate that automation [UPC systems] should lead to a net savings before tax for retailers equal to 1.0 to 1.5 percent of sales, essentially due to quantifiable reductions in productivity costs. For example, a $40,000 per-week retail store should expect to save $27,000 before taxes the initial year of operation, after subtracting depreciation, cost of capital, and other costs [21:39].

In addition to the productivity savings, retailers are expected to derive substantial long-run savings from product usage forecasting based upon the data generated daily by the UPC system.

A major supermarket chain is making extensive use of the data obtained from the automated checkout stands.

For the first time this chain is in a position to receive fast feedback on advertising and promotions to determine what strategies have or have not worked. A report is then developed to identify items that move less than a case per month. By getting rid of the grocery departments' slow movers, more room is available for higher profit lines (58:52). Additionally,

> Price elasticity is proving another potentially rich road to higher profits. Such testing involves both lowering and raising retail prices on specific products in an attempt to optimize gross profit dollars at the category level. Scanning, because of information accuracy and ease of accessibility, makes this type of testing practical, timely and more reliable [58:54].

Though the benefits to be gained by the retailer are great, they will not be realized without some difficulties. One of those problems is the legal liability for losses resulting from bar codes that do not scan properly. In other words, who pays for a supply of faulty labels: the retailer, the wholesaler, the printer, or the materials supplier? One industry publication, <u>Paperboard Packaging</u>, has described the current situation as follows:

> A . . . [printer] who prints a UPC symbol may not have the symbol rejected for either qualitative (appearance and printability gage determinations) or quantitative (measurements of lines and space widths) criteria when he delivers his cartons to the packager--his customer. The packager then erects, fills, closes, seals, packs and ships his merchandise. This customer removes the merchandise and then puts it on the shelf where it is pushed, scuffed, rubbed, scraped, and then put across a scanning window which may be scratched, marred, covered with oils, grease, fat, dirt. Now,

> if the symbol will not read, the . . . [printer] is held potentially liable for not having printed a readable symbol [53:31]!

Who is at fault? The solution to the question of legal liability is not expected to be fully decided until the use of bar coding at the checkout counter becomes more prevalent and attorneys and courts have established the essential precedents (53:31-34).

Department of Defense. As previously indicated, the many applications of bar coding within industry have sparked considerable interest in the subject within the DOD. In order to insure a coordinated effort among the Services, the Defense Logistics Agency, and other defense agencies, the Assistant Secretary of Defense (Installations and Logistics) requested the establishment of a Joint Steering Group to study Logistics Applications of Automated Marking and Reading Symbols (LOGMARS). The Army Materiel Development and Readiness Command Packaging, Storage, and Containerization Center (DARCOMSPCC) was selected to provide a chairman to head the study. The group is specifically charged with assuring the establishment and maintenance of DOD-wide procedures for the marking of all logistics data on items of supply. The group was given two years to complete the study (1977-1978) (62:131).

Prior to the establishment of the Joint Steering Group, the Army (DARCOMSPCC) had already been studying the

use of bar coding (32). Their report, which was published in October, 1975, concluded that there are at least seven areas in the Army Materiel Center depots and Containerization Control Points (CCPs) to which bar coding scanning is potentially applicable, these being:

> . . . marking and consolidation of conveyorized freight, parcel post sortation, location survey, location addition/deletion, and receipts and intransit data processing [32:6].

The Army is currently testing an intelligent printer (intelligent because it has a minicomputer in the printer) and applicator in the System Wide Project for Electronic Equipment at the Depots, Extended (SPEEDEX) which is the automated, integrated, standardized data processing system used by depots. Using this printer, SPEEDEX would use a bar code label to make shipping labels for all containers going to a specific customer on a given day. The intelligent printer and applicator would automatically print and apply all needed labels (33:4).

> Bar code scanning . . . [would] be the means to activate the marking mechanism in the process. A six-character shipment planning worksheet serial number is the key to each customer address in computer files. It appears in various shipping documents, including DD Form 1348-1A, Department of Defense Single Line Item Release and Receipt Document, which follows a shipment throughout the distribution pipeline. Using a small typewriter-like bar code printer, one employee in a packing activity could key in the serial number and quantity of containers requiring the address, and he would immediately obtain a pressure-sensitive bar code label depicting the serial number and quantity. The label could be placed on one side of the first container of all containers under one serial number on a

> conveyor, and the label could be scanned by a rotating beam scanner to activate the automatic preparation and application of address data [33:5].

The Army is also considering the use of bar coding in sorting small parcels by the activity address label. Automatic sorting is already being accomplished at one CCP. The system is controlled by a cathode ray tube with a keyboard manually operated by a single employee. To accomplish the automatic sorting currently, the last four characters of the six-character activity address code and the priority of each small parcel are keyed in manually (33:4-5).

> With computer reprogramming, a rotating beam scanner could replace the cathode ray unit and the operator requirement, accomplishing the same functions through bar coding and the activity address codes on the parcels [33:5].

Though the literature review indicates the primary DOD user of bar coding has been the Army, the Navy did implement a bar code system in its SERVMART stores at Charleston and San Diego. The SERVMARTs primarily handle administrative and janitorial supplies. All items that can be bar coded are marked. If an item is too small for a bar code to be affixed, a tag is tied to the item and the bar code label placed on the tag. The results of the initial testing were positive, and the adoption of bar code labeling at other Navy SERVMARTs has been recommended (64).

Another Navy application involves the proposed use of optical bar codes for ship construction/modification

equipment validation. Because of the complexity of ship construction/modification, there is a need to know precisely the current equipment serial numbers, quantities, location (deck, frame, compartment, work center), and in general the overall configuration of the ship. In order to obtain this information on a current basis, the Navy expects to use a portable pen-scanner in conjunction with a label affixed to each piece of controlled equipment in order to precisely monitor the current location, type, and status of equipment onboard the ship (63).

The Air Force has also made some initial attempts at applying bar code technology. The Military Airlift Command is investigating the use of a bar code system for data gathering at its aerial port activities. This effort was tested at Dover AFB, Delaware, in 1975 (34). In another application, the Air Force Logistics Management Center, Gunter AFS, Alabama, expects to test a small point-of-sales system at Gunter and also Charleston AFB in 1978 (11).

In addition to these projected applications, the Air Force recently entered into a contract with NCR Corporation to install their Model 255 supermarket point-of-sales system in eighty-eight Air Force commissaries, world-wide (44). Although the initial version is electronic, it does not include a scanning capability. Since the system is modular, a scanner can be added at a later time. Whether it will be upgraded to a full bar code scanning system is

partially dependent upon a test currently being conducted at Rome Air Development Center (Griffiss AFB, New York). This test is evaluating the Sperry Univac Accu-Scan supermarket checkout system at their commissary. Results during this test will definitely have an impact on any decision tc upgrade the NCR equipment to full scan capability (56).

As you can see, the literature reviewed has provided considerable insight into the general nature of bar code systems and to their applications within industry and DOD. The remainder of this chapter deals with the justification for the conduct of this research, the scope (or how broad the subject was defined), the delimitation (what the thesis does not address), the objectives or goals of the research, and finally the objectives rephrased into specific researchable questions.

Justification

Bar coding technology appears to be highly developed and has been successfully applied to many areas within industry. Since many of these applications have direct military counterparts, it is logical to assume that bar coding could similarly be applied to those activities. The areas concerned include, but are not limited to, the following: supply management, inventory control, transportation and cargo management, commissaries, and hospitals.

As previously indicated, DOD has already begun the investigation of several of these applications. The use of a UPC symbol in supply systems has already been studied by one Army researcher (54). The Army Materiel Command sponsored another study focused on the application of bar code systems to the conduct of physical inventories (17). Two studies concerning transportation management have been published, one by the U.S. Army Advanced Materiel Concepts Agency covering theater transportation in the 1990 time frame (60) and the other a study of Worldwide Cargo Transportation Management by the Institute for Defense Analyses (27). It appears that interest in the use of bar code technology has increased considerably within the DOD.

With the increased interest, many applications have been and will continue to be proposed. In order to evaluate which applications will be most amenable to this technology and provide the greatest benefit, a broad survey of the types of bar code symbols, equipment, applications, implementation problems, and DOD experiences with bar coding, is necessary. This research will then provide the basis for future, more specific investigations.

Scope

This research is limited to a determination of how the Air Force could apply available optical bar coding technology.

Delimitation

This research does not address nonoptical bar code scanning systems. Specifically excluded are magnetic or electromagnetic scanning systems. Additionally, the optical reading technique referred to as Optical Character Recognition (OCR) is not included in this research.

Objectives

1. Identify factors that have impeded the implementation of bar coding technology in the Air Force.

2. Identify bar code symbols, equipment, and applications available from industry, and to recommend general and/or specific areas where bar coding technology can be applied within the Air Force.

3. Identify some of the problems that would be associated with the implementation of bar code technology in Air Force activities.

Research Questions

1. Why has the Air Force not made extensive use of bar coding technology?

2. What types of bar code symbols, equipment, and applications are available from industry, and what general and/or specific areas are amenable to bar code system application within the Air Force?

3. What are some of the problems associated with implementing bar code technology in Air Force activities?

CHAPTER II

RESEARCH METHODOLOGY

Overview

This chapter outlines the procedures used to gather and analyze the information necessary to address the research questions posed in the previous chapter. More specifically, it focuses on how information was obtained from the manufacturers and users of bar code systems, and provides the factors and procedures used in the analysis of that information. The data gathering plan is discussed first, followed by the data analysis methods, and finally some general methodology considerations.

Data Gathering Plan

The information required for this research was obtained by a variety of means including telephone and personal interviews, written requests for materials, field observations of operational bar code systems where convenient, and by continued survey of the literature. The initial activity was to contact the various manufacturers of bar code systems for information relating to the types of codes, scanners, and systems in existence or under development. In addition to obtaining the specifications, capabilities, and uses of the various items of hardware,

a listing of clients who have installed the equipment was requested. A representative portion of these users was then contacted to secure information relating to the specific application of the system and other information required for analysis (see Data Analysis section). These two approaches then provided sufficient information to accurately portray the current and projected applications of bar code systems in industry and their nature and degree of success.

Another phase of data gathering was focused on DOD (especially Air Force) activities. All offices/organizations contacted were either directly involved with current or proposed applications of bar coding, or were engaged in studies dealing with the use of this technology. A listing of bar code equipment manufacturers and users is provided in Appendix C.

The final phase of data gathering involved visits to some of the local users/manufacturers of bar code hardware or systems. Specifically, those visited were the National Cash Register Headquarters, Dayton, Ohio; Marsh Supermarket, Troy, Ohio; and Hobart Manufacturing, Troy, Ohio. HQ AFLC/XRB, Wright-Patterson AFB, Ohio, was contacted and various Air Force applications and potential applications of bar code systems were discussed. Follow-up visits and inquiries were conducted as necessary.

Data Presentation

Information gathered from equipment manufacturers and users is discussed in Chapter III. The discussion includes a description of the hardware, systems, and specific applications.

Data Analysis

The analysis of the information gathered was directed at answering the three research questions presented in Chapter I. The first question was addressed by subjectively evaluating responses from Air Force and DOD sources to determine why the use of bar coding is not widespread within the Air Force. The second question, dealing with the identification of the recommended applications of bar code technology, was evaluated by analyzing the following factors:

PRIMARY FACTORS

1. Cost
2. Manpower requirements
3. Time savings
4. Accuracy of operation
5. Reliability of equipment

SECONDARY FACTORS

1. Problems encountered with implementation/operation
2. Personal feelings of people concerned with system
3. Other advantages/disadvantages

Since no generally accepted criteria have been developed against which each factor considered can be evaluated, a subjective evaluation appeared to be the most

viable alternative. It was decided to use a matrix format to display the information obtained from manufacturers and users relating to the primary factors. This information was then analyzed to determine apparent positive or negative trends. Although this procedure may provide some useful information regarding the impact of applying bar code technology to certain activities, the HQ USAF and Air Force Logistics Management Center bar code systems representatives indicated that any decision regarding the specific application of bar code systems would require an overall cost-benefit analysis against a variety of qualitative and quantitative factors (11; 34).

The last objective of this research was to address problems associated with implementing bar code systems. This will be accomplished by analyzing the assembled data in the perspective of the question, "Would similar problems be likely to occur in a comparable Air Force application?"

Other Methodology Considerations

A continuing effort was made to survey data available from the Defense Documentation Center, Defense Logistics Studies Information Exchange, the AFIT School of Systems and Logistics and the School of Engineering libraries, Wright State University library, and the Dayton Public Library. Personal interviews of AFIT faculty, staff, and students knowledgeable of bar code systems were also conducted.

CHAPTER III

DATA PRESENTATION

A considerable volume of information was received in response to our letters forwarded to bar code equipment manufacturers and users. Of the total forty-one letters forwarded to manufacturers, twenty-two responded (53.7 percent). Fourteen of those twenty-two responses (34.1 percent) were useable for our analysis. Useable responses were those that either addressed one or more of the primary or secondary factors described in Chapter II, or contained brochures, letters, advertisements, reprints, or specification charts regarding equipment characteristics or capabilities, or described a particular application. The bar code equipment user response rate was somewhat lower (twenty-three out of forty-nine for 46.9 percent), but had a higher useable rate of twenty-two out of forty-nine for 44.9 percent. The overall useable rate from both sources combined was thirty-six out of ninety, or 40 percent. Many letters, brochures, tables, equipment manuals, and specification charts were provided, along with many descriptions of bar code applications. This section of the thesis examines those applications and provides a summary of the types and characteristics of some of the

various items of bar code equipment available. Equipment descriptions were obtained from advertising brochures provided by equipment manufacturers.

Manufacturer Equipment Descriptions

The following brief descriptions provide a representative sample of the types, capabilities, and cost ranges of bar code equipment available from industry. They are not intended to be detailed or exhaustive, merely representative. An alphabetical arrangement of the equipment descriptions was selected for convenience.

Accu-Sort Systems, Inc.

Moving Beam Scanner. The Series "M" scanner is a laser source, moving beam scanner. It uses microprocessor technology to accommodate any code. Options include malfunction warning and readouts.

Fixed Beam Scanner. Model 402 reflex scanner is used with retroreflective discs or tape. Laser model can be used where the distance exceeds thirty feet. The Model 422 reflective scanner is used for automatic sortation and recognizes up to sixty-four different codes in almost any color at speeds to two hundred feet per minute.

Hand-held Scanner. Model 4600 pen scanner reads a variety of codes up to twenty-four characters in length. It possesses a mini-memory and storage unit that permits full programming.

Complete Systems. Complete management information systems using moving and fixed beam scanners, hand-held scanners, CRT displays, and teletype are available.

Verifiers. Safe-T-Check verifiers are used to read miniature codes on small containers that are essentially identical in appearance. Some examples are photographic film and health-related products.

Decoder. Designed to interface with the Series "M" scanner, this decoder employs an advanced microprocessor that incorporates Large Scale Integration (LSI) technology.

A.P.D. Security Systems

Scanner. The 711 Memory Central Access System uses the recent technology of Differential Optics to provide a sophisticated security control system. Plastic access cards contain optical filters, that when inserted into the reader slot, are scanned and decoded. No bars or marks are visible on the outside of the card. Central control units accept up to eight thousand cards. Options available include a weather resistant reader enclosure and a cold weather model. This system records every entry attempt including: date, time, and location. Invalid attempts are listed in red. The 740 series Memory Card Lock (similar to 711) can be used with up to four thousand different cards. A card alarm for voided or stolen cards is optional.

Checkpoint Systems, Inc.

Checkpoint is the marketing representative in the United States for the Plessey (Great Britian) Light Pen System for libraries.

Hand-held Scanner. The Model 1450 Portable Data Capture unit can be employed with either its integral keyboard or the model 1050 light pen or both. The 1050 pen can operate at a somewhat wider range of reading speeds than other pen readers.

Printer. The Plessey Model 2101 Label Printer can print bar code labels compatible with its equipment at two thousand to three thousand per hour depending upon length.

Other Equipment. Series 2920 Tape Converters are designed to re-record data previously written on Plessey data cassettes onto a standard computer compatible tape.

Computer Identics Corporation

Moving Beam Scanner. The Computer Identics' scanner is a laser source reader which can scan all types of numeric and alphanumeric codes. It provides a generous scan height and depth of field.

Hand-held Scanner. Three versions of the Fixed Code Processor II are available. These devices are stationary bar code entry terminals that provide numeric, alphanumeric, and verifier capabilities. Scan velocity of these pen readers is up to forty-five inches per second (faster than most).

Printer. The Identic Bar Code Printer produces Two-of-Five and Interleaved Two-of-Five codes only. It has an optional automatic label applicator for on-line application of labels.

Other Equipment. The Decodatran decoder has a bracket or rack-mount capability. It has a wide variety of output interface formats. The Remote Asynchronous Message Multiplexer (RAMM-16) provides sixteen input/output devices the capability to simultaneously communicate with a host computer via a single communications link.

Data Terminal System

Scanner. The Model 540 Scan-alone Supermarket Point-of-Sale system has two-way communication capability with a host computer over telephone lines. This eliminates the need for an in-store computer, but still provides large computer capability.

Identicon Corporation

Moving Beam Scanner. The Identicon 400 scanner is for production and warehouse applications. It uses a laser source and can read many different types of labels.

Fixed Beam Scanners. The Model 100 was developed for use in harsh external environments (wind, rain, snow, dust, vibration, or chemical). It uses a quartz-iodide incandescent source and must be used with retroreflective labels. Various other fixed beam read heads are also available.

Hand-held Scanners. Several models and individual pens are available. Some models include a keyboard backup

to the scanner. The new Porta Pen III is lightweight (one and one-half pounds) and provides a large forty-one-key alphanumeric keyboard.

Other Equipment. The Identicon UPC Verifier can check film negatives or positives, proofs, press sheets, production runs, or warehouse products. The print contrast ratio is also provided by this device.

INTERMEC

Hand-held Scanner. The Models 9210 and 9220 are portable units that can be used to scan Code 39 or can be modified for other codes. They can accept scan rates from three to fifty inches per second and up to thirty-two characters of encoded data.

Printer. The 8100 series Impact Printer incorporates a microprocessor that enables it to print virtually any common bar code format. An automatic applicator for label application is also available.

Other Equipment. A Model 9153 multiplexer is available to permit up to sixteen simultaneous communications between scanners and the host computer.

Markem Corporation

Printer. Two models, the U-1231 and U-1233 provide bar code label capabilities with one or two additional lines of print respectively. Only linear bar codes are produced. Up to one hundred labels per minute can be printed, depending upon the size of the label.

Monarch Marking Systems

Moving Beam Scanner. The Model M-2200 laser, moving beam scanner can be used for scanning CODABAR tickets or labels.

Hand-held Scanner. Models M2243 and 2246 perform the function of reading, decoding, and error checking of bar code labels. These readers possess an internal storage capacity and their pens can scan through transparent packaging.

Printers. Several different models are available. The Dial Printer (Model 104) is larger than most bar code

printers and uses dials rather than a keyboard to enter label data. A unique feature is its "constant impression" technique for printing the labels. Models 2050 and 2052 are typewriter-style printers that are fast and efficient. Sequential numbering is an available option. A rotary bar code printer (Model 2023) is also available.

Other Equipment. A bar code label verifier is available with an optional digital readout. For the mass processing of bar code labels on price stubs used in department stores, a batch reading system is available.

MRC Corporation

Moving Beam Scanner. The Model 7101 optics unit is the heart of the MRC scanner system. It is a moving beam laser scanner which can successfully read symbols moving through its field of view at five hundred feet per minute.

Other Equipment. The Model 6214 decoder is available for use with the 7101 optics unit. It has various input/output formats and character display options.

National Cash Register Corporation

Moving Beam Scanners. The NCR 255 Supermarket Terminal System uses a horizontally mounted, moving-beam laser scanner in the checkout counter. Optional equipment for this terminal includes an electronic scale, automatic coin dispenser, remote display device, and communication and data collection devices.

Hand-held Scanners. The Model 7877 UPC hand-held scanner reads the same data as the scanner installed in the 255 terminal system. It is used primarily for large or bulky items that the customer may have placed under the grocery cart. In addition to a regular (726) processor, this scanner also needs additional storage facilities. Either the NCR 656 Disc or 651 Drum storage units can meet this requirement.

Other Equipment. The Model 726 Controller provides a central processing capability for the NCR 255 terminal system. Peripheral storage units, as mentioned above, are also available.

Sperry-Univac

Scanner. Various models of the AccuScan supermarket checkstand are available for use with the UPC. Other symbols can be used with some of their equipment.

Weber Marking Systems, Inc.

Printers. Several printers are available. The Models 83, 85, and 88 are used in a variety of applications to provide maximum flexibility for product changes.

3M Company

Printers. Three printers are available, the LB-101 UPC bar code printer, another printer that prints a special UPC label for airline baggage sortation, and a random weight printer for meat or produce applications. All three printers use an electronic technique for printing rather than an impact method. An optional label applicator is available with the random weight printer.

Since many manufacturers requested that their price information not be included in our report, no prices are provided for specific equipment; however, the following guidelines may be helpful to the reader. Moving beam scanners generally ranged from $3,000 to $10,000. Usually the higher-priced version included a decoder unit along with the scanner. Hand-held scanners varied from about $1,000 up to $3,000, while printers ranged widely from $900 to $60,000. The most popular printers generally run about $10,000. The only other item of equipment for which a price range could generally be established was the multiplexer, which ranged from $2,500 to $3,500.

From the preceding information, it is apparent that a wide range of bar code and support equipment is available

to potential users. Equipment costs vary considerably but seem reasonable, especially for large applications. A more in-depth analysis of the data collected is presented in Chapter IV.

Applications

Examination of the information received from industry indicates the applications of bar code technology are many and varied. The more common applications include inventory control, sorting of cartons on conveyor lines, and production of management information reports as the result of scanning bar codes. The less common uses include: insuring blood transfusions are accomplished accurately, that airline baggage is expeditiously routed to the correct aircraft, and that automobiles have the correct emission control devices installed. These are only a few examples of the many applications of bar coding that will be discussed.

Automotive

The automotive industry has found several applications for bar codes. Chrysler's principal use of bar code reading technology involves the configuration certification of vehicle emission control systems. An inspector uses a wand scanner to read the bar-coded vehicle identification number and five to eight bar code labels on carburation units. This data goes to the computer files where the

component numbers on the vehicle are matched against the vehicle's specification tables. Any discrepancies are shown on a CRT at the inspection station, recorded in the vehicle record, and flagged for correction as the vehicle moves down the assembly line (9).

The Pontiac Division of General Motors is making the same application as Chrysler at its Pontiac, Michigan, plant. In addition, Pontiac has a nonemissions use for the bar code. As the body of the automobile begins to move down the production line, an automatic laser scanner reads a bar code label which outlines the options that are to be included on the vehicle. Previously, an inspector would walk up and down the line writing down the vehicle number and matching it to the order. The manual system practically guaranteed some mistakes (6).

The Chevrolet Division, Buffalo, New York, produces twenty-one styles of automotive rear axles. They are built in random order and transferred to an overhead power conveyor which moves them to a marshalling area for loading onto shipping racks. A label that has an alpha designation and a bar code pattern that identifies the particular style of axle is applied to one end of the axle during assembly. The label has two identical bar codes that are at right angles to each other. This reduces the need for careful positioning of the label and the scanner can identify one of the code patterns regardless of the orientation of the

label. As the axle moves past the optical scanner, the code pattern is read, and the computer activates a magnetic print-head which codes an address on a metal tag attached to the axle. The code address remains attached until the axle is transferred to the shipping rack (50).

TRW, Inc. employs moving-beam optical scanners to identify and sort cartons of automotive parts prior to shipment from its Cleveland distribution center. Reuseable vinyl labels are attached to open containers, and stick-on paper labels are used for sealed cartons. As the cartons are identified by a scanner, a link in the conveyor chain is positioned so that it can be sensed by a limit switch. When the switch is contacted by the link, it activates a diverter which sweeps the carton from the conveyor. The system has been easy to maintain and is capable of expansion (46). These are examples of the uses of bar coding in the automobile industry. Responses received indicate that research is continuing for further applications and more uses can be anticipated in the future.

Airlines

The principal use by airlines has been for baggage handling. Eastern Airlines and the Bendix Corporation developed a baggage handling system for Eastern Airlines at the Miami International Airport that uses bar codes to route baggage to the correct baggage holding area. The

system is a mix of conventional conveyors, a bar code printer, and an optical scanner. A bull's eye-type bar code is produced during baggage check-in and applied to the luggage. As the bag travels along a main conveyor, it passes under the reader where a scanning laser beam bounces signals to the reader. The signal is decoded by a minicomputer which stores the sequence of bags in memory and activates a moving arm that sweeps each bag into the correct spur that leads to the baggage holding area (10).

Though the original intent of the system installed at Miami International was to provide Eastern with a ninety-day test program to determine whether or not the system should be extended to other airline terminals, the test (which began in 1973) is still being conducted. A firm decision as to what type of system will be used to automate baggage handling for Eastern Airlines has not been made, although the type of system installed at the Miami International Airport is certainly a possibility (15).

In addition to the Bendix system being used by Eastern Airlines, the 3M Company, on a joint basis with Rexnord, Inc., has developed a similar baggage handling system. This system employs a long paper strap that is wrapped around the baggage. The strap carries a custom UPC label rather than the bull's eye code used by Eastern Airlines (5).

Meat Packers and Processors

The meat packing industry has begun using bar codes for sortation and inventory control. Iowa Beef Processors, Inc., is the world's largest beef packing and processing company (57). Their processing operation and distribution center in Amarillo, Texas, has installed an automated system that uses bar coding as a key element in sortation and inventory control. Packers place a bar-coded label on a carton at the start of the system. After the carton is packed with one of the twenty-three varieties of meat, it is placed on a conveyor line. An optical scanner reads the bar code symbol and signals the central computer. The computer then selects the proper route for the carton from among the one hundred sortation lanes available. When eighteen cartons accumulate on a lane, they are routed to the pallet-loading machines (57).

Another scanner checks to insure all eighteen cartons are of the same variety. If an incorrect carton is present, it is diverted to an area where it is checked prior to entering the conveyor system again. Pallet loads are automatically routed to storage locations where they remain until needed for shipment. The pallets are automatically removed from storage when required and scanned to insure the proper variety was selected. The pallets are automatically broken down into the desired order size as the load moves to the shipping dock. As the last carton

in an order passes another scanner, the computer actuates a line printer which creates the customer invoice. The total operation is so well coordinated that the paper work is usually waiting at the dock as the truck is being loaded (57).

Frigid Meats, Inc. of Chicago uses bar codes to sort cartons of portion-controlled meat products and for inventory control. Though the system is not as automated as the one described above, labels are scanned with a light pen to enter the carton into the inventory and scanned again by a fixed beam scanner as the carton is sent to the dock for shipment. The scanners are interfaced with a computer which maintains a current inventory and prints production, shipping, and inventory control reports in addition to producing shipping manifests (67).

Automated Warehouses

Rust-Oleum's plant in Hagerstown, Maryland, is an example of an automated, high-rise warehouse that uses bar coding for sortation and control. Prior to the cases entering the sortation system, the conveyors coming from each of three levels merge onto one belt conveyor that moves the cases and transmits the information encoded on the label to the computer. When the computer receives the information relayed by the scanner, it recognizes that a case has been selected from storage. If an error has been

made either in kind or quantity, or if a label is not scanable, the case will be rejected and moved back to the sortation operator's station. For cases that are accepted into the system, the conveyor carries them along until they are routed to the correct shipping lane (48).

Eagle Rubber Company, Inc., Ashland, Ohio, manufactures a variety of rubber and vinyl toys and sporting goods. They have recently built an automated warehouse where a laser beam scanning system reads bar code labels on cartons and directs the cartons by conveyor to different warehouse areas where they are manually removed from the conveyor system and stored. During the scanning process, a production report is generated by the computer as the cartons move past the scanner (66).

When cartons are ready for shipment, they are returned to the conveyor and move past the scanning system to direct the carton to the proper rail or truck loading dock. The system simultaneously reports cartons being shipped in order to prepare the shipping report. In addition, packer identification is read from a separate bar-coded label affixed to each carton to produce a report from which packers are paid. The system has been quite beneficial to Eagle Rubber Company (66).

Rather than have a company print bar codes on their cartons, Eagle Rubber Company has purchased a Weber Model 88 label printing system. In order to print the labels,

variable data and the bar code are inserted into the printer in the form of pressure sensitive rubber slugs. The label counter on the printer is set, and the desired number of labels are produced. The printing and scanning system have provided increased inventory control at reduced cost (66).

Clothing Manufacturers

Levi Strauss uses optical scanners to read the bar codes on the approximately nine thousand cartons of slacks and tops arriving daily at one of its distribution centers. The bar code includes quantity, style, color, and size of contents. If the label is misplaced or damaged, the carton is routed to a quality assurance line. In addition to the use in the receiving area, scanners at the shipping docks provide data necessary to prepare the shipping manifest which is ready before the truck leaves the dock (25).

A southern knitting company attaches a preprinted bar code label that shows size, color, and style to each garment produced. Upon completion, the bar code is scanned and inventory records updated. The label is read again when the garments are removed for shipment. Bar coding has provided significant improvement in their inventory control (24).

Hospital Applications

Bar coding is also being used to eliminate mistakes during blood transfusion. In this application, a hospital patient will wear a bracelet showing his blood data in CODABAR (a type of bar code). Refinements to the current system will physically prevent a transfusion when an optical scanner shows that the code on a patient's bracelet does not exactly match the code on a blood container. To insure the blood in the container is as shown, a bar-coded identification number is placed on the primary blood bag, blood sample test tubes, and on the donor's record. At the present time it is estimated that 5 percent of all blood recipients are administered the wrong kind of blood. The precautions outlined above should virtually eliminate the problem (49).

The Riverside Hospital in Columbus, Ohio, is applying bar coding as a part of its security system for a drug control room. The APD Security System uses a differential optics bar code (invisible to the human eye) on a card which opens the locking mechanism on the drug control room door (51).

Other Applications

Thom McAn is the first company reported to have designed a receiving operation that takes full advantage of optical scanning of bar-coded products and computer

control. Bar-coded labels and a purchase order are generated by the computer at the same time. Both documents are then forwarded to the supplier. The bar-coded label serves as a shipping label, but a portion contains data such as supplier identification, order and due date, purchase order number, and a sorting lane number. The supplier applies the preprinted label to the carton when it is ready for shipment (1).

When the case arrives at the distribuiton center, the label is scanned, and the computer matches the case number to the information previously stored in its memory. Part of the data stored is the amount the case should weigh. An in-motion scale weighs each case to insure it is within tolerance and routes it to an inspection line if it fails the weight check. If the case passes the weight check, the central computer updates inventory, accounting, and billing records. The bar-coded label is also used to trigger the automated sorting equipment at the distribution center. As the bar-coded case passes a scanner, the computer determines to which of the nine sortation lanes the case will be routed. This automated distribuiton center has helped Thom McAn to ship 98.5 percent of its orders complete (1).

A rather unique application of bar coding for inventory control has been developed by the Federal Reserve Bank in Boston. It uses optical bar coding equipment as

part of a vault storage inventory control system for coins and currency. Bar-coded labels are attached to pallets and containers used to store coins and currency (19).

The Remington Arms Company is installing optical scanning units at its Ilion, New York, plant. A bar code will be used to record the serial number of the firearm on the gun carton. The bar code is then scanned at various points to determine when the gun is packed, sent to the warehouse, and shipped from the warehouse. The serial number information is important because it must be reported to the Alcohol, Tobacco, and Firearms Division of the U.S. Treasury Department (18).

A retail department store, S. P. Dunham in Trenton, New Jersey, has developed an interesting application. A bar-coded tag is applied to merchandise as it comes into the receiving section. The specially designed label has a partial adhesive backing that is placed on the merchandise. The bottom portion of the label contains the bar code, but this section does not have adhesive and can be easily removed at the point-of-sale. The bar code is scanned after the sale is made (hand-held or batch scanner) and data entered into the store's computer which is then able to expeditiously provide management information reports.

One application of the Monarch CODABAR system has been to keep track of items that are sent to a repair facility. When a consumer product is received, it is

identified with a CODABAR label that remains with it until the item returns to the customer. The ability to access the computer and find out the location and status of the product has been of great benefit in the area of customer relations. Advantages other than customer relations include identifying whether or not the item is covered by warranty, and the ability to prepare an invoice when the item is not covered. When the product is ready for return to the consumer, shipping and postage insurance labels are automatically prepared by reading the CODABAR label. The item is then shipped to the customer (39).

Many manufacturers, wholesalers, and retailers who inventory a lot of small parts or products use the CODABAR system to replenish stock. A bar-coded label containing information required for stock replenishment is attached to the bin where the parts or products are stored. By using a hand-held scanner connected to a portable recorder, stock clerks can quickly and accurately read the shelf label and record replenishment requirements. The recorded data is then sent to a data processing center where replacement orders are generated (40).

Photograph processors are using envelopes with a CODABAR imprint to invoice and control customer film in their laboratories. As film is received for processing, the envelopes are scanned and the kind and number of prints are key entered into the system. When the processing is

finished, the envelope is scanned again and a terminal automatically prints the number of copies, kind, and price on the envelope (40).

A northwest firm that deals in inventory control for several logging companies is in the process of purchasing equipment that will allow it to trace the owner of each log from the time it is cut until arrival at the mill. A laminated vinyl bar code tag will be attached to the end of each log. A hand-held scanner will be used to read the tag upon arrival at the mill, and the information will be sent over telephone lines to the main company computer (29). The system should greatly improve control over the current manual inventory method.

To aid in sorting products to palletizing machines, Colgate-Palmolive Company is using a laser beam scanner to read bar codes that are preprinted on the cartons. Identification must be fast and accurate as the first sortation lane is only three feet from the scanner, and the conveyor speed is two hundred feet per minute. The entire identification, encode, sortation cycle has to be initiated and completed within seconds. The system has helped Colgate-Palmolive achieve a better than 99 percent sortation reliability rate (8).

Phillip Morris uses a bull's eye bar code to keep track of each arriving one-thousand-pound container of tobacco at its Richmond, Virginia, plant. As the container

of tobacco (hogshead) arrives at the plant, an optical reader in conjunction with a mini-computer controls sorting and storage actions. Accurate tracking is vital because the correct type of tobacco must be used for proper blending of each brand of cigarettes. When the hogshead is required for production, the mini-computer controls the equipment that automatically removes the hogshead from storage and routes it to the processing building (42).

Potential Applications

The Villanova University Library has an automated circulation control system similar to those discussed in the Applications section of Chapter I. Because the bar code is an integral part of the student identification card, they are considering using the bar-coded card to monitor students eligible to use the dining hall, check the student's age for entry into the rathskeller, and for verifying student data during registration. Though these uses are only in the proposal stage, a properly encoded student card would make them feasible (14).

A leading cosmetics distributor plans to use bar codes to track orders through assembly and packing areas and to establish status against required shipping schedules. In addition, they plan to use scanning of a bar code label to access the customer's name and address from their computer which will then cause the information to be spray-printed on individual order units.

Summary

The equipment and applications reviewed indicate that there are many ways to employ bar code technology. Efforts are currently underway to evaluate additional areas that can successfully utilize the bar code equipment available. From the uses that have been described, it is clear that there is a broad frontier available for exploration.

CHAPTER IV

ANALYSIS

This section provides an analysis of the data gathered over the course of this research. The analysis is divided into two sections; the first portion deals with a discussion of the primary factors established in Chapter II. These factors were: cost, accuracy, reliability, manpower, and time. The second portion of this chapter investigates the secondary factors which were also identified in Chapter II. These factors were: problems encountered with implementation and operation, personal feeling of people concerned with the system, and other advantages and disadvantages. The data obtained during this phase, and other information already provided in the thesis were then used to derive answers to the three research questions posed in Chapter I. These answers are provided in Chapter V.

Primary Factors

The primary factors shown in Table 1 represent a summary of information taken from letters and articles received from manufacturers and users of bar code equipment. Examples of the letters forwarded to respondents are provided in Appendix D.

TABLE 1

PRIMARY FACTOR MATRIX

Factor	Impact	Manufacturers	Users
Cost	Positive	14.3%	31.8%
	None	-	31.8%
	Negative	-	-
	No Comment	85.7%	36.4%
Accuracy	Positive	50.0%	90.9%
	None	-	-
	Negative	-	-
	No Comment	50.0%	9.1%
Reliability	Positive	14.3%	36.4%
	None	-	4.5%
	Negative	-	-
	No Comment	85.7%	59.1%
Manpower	Positive	35.7%	59.1%
	None	-	9.1%
	Negative	-	-
	No Comment	64.3%	31.8%
Time	Positive	35.7%	40.9%
	None	-	13.6%
	Negative	-	-
	No Comment	64.3%	45.5%

From the matrix it can be observed that most users and manufacturers mentioned accuracy as the most significant positive impact on their operations. This factor was clearly viewed as a significant advantage to be gained through the use of this technology. The accuracy rate of equipment noted in the literature was essentially 100 percent.

Manpower was the second most improved area resulting from the application of bar code technology. Fifty-nine percent of the users indicated that manpower savings had occurred. The Milwaukee County Federated Library System reduced manpower requirements by twenty people when their bar code system was installed (16). The Chevrolet Motor Division plant at Buffalo, New York, eliminated a repetitive, boring job by using a bar code to aid in sorting assembled axles (50). Eastern Airlines required fifteen less baggage handlers in their automated terminal in Miami (10). Only 9 percent of the users that responded indicated that no reduction in manpower had taken place.

In addition to accuracy improvements and manpower savings, many users were able to reduce their processing time substantially. The Air Force Academy Library was able to reduce checkout time per item from one minute to less than ten seconds (7). Stanley Hardware has been able to reduce the time to process orders from three weeks to

twenty-four hours. Only three of the twenty-two users responding indicated that no time savings had resulted.

Reliability of equipment was mentioned by eleven of the thirty-five users and manufacturers responding. Only one of the comments was somewhat unfavorable. The Colgate-Palmolive Company and a leading manufacturer of cosmetics commented that reliability of equipment had been excellent, though trained mechanics were needed for maintenance and repairs (8).

In the area of cost, only 14 percent of the manufacturers indicated there would be lower cost resulting from the application of bar coding; however, 32 percent of the users commented that cost had been reduced when bar coding was applied. This seems to imply that users are finding more cost savings than manufacturers had anticipated. Although specific cost savings were referenced in only two instances, the annual savings indicated were $250,000 or more (42).

Secondary Factors

In reference to the secondary factors, the general comments made by both manufacturers and users of bar coding equipment were positive. This is evidenced by the fact that five users specifically stated in their responses that additional uses of bar coding were under study for future applications. Another positive note is that there

was only one instance, in addition to consumer complaints regarding UPC noted in Chapter I, where resistance to the application of bar coding was noted. This was a result of an additional work load for personnel responsible for applying the bar code tags to merchandise (43). The management of that company was very satisfied with the overall results of the entire system.

One advantage of bar coding frequently noted by users was that the accuracy of management information had increased, and new types of management data were available. This was most often noted by retailers, though other manufacturers and users made similar comments (1; 16; 43; 50). The reason for the increased accuracy of the data was that human errors made when manually annotating or keying in data had been eliminated.

Another advantage of special concern to distributors was the increase in throughput. Several distributors commented that scanners reading bar codes had enabled an increase in sortation of products on conveyors resulting in more expeditious processing of products into and out of inventory (1; 48). This is especially true in warehouses that are highly automated.

Disadvantages noted by equipment users were few. Those comments made were generally in reference to a particular problem experienced by a user. The only disadvantage continually noted by users was that back-up manual

systems were not efficient (1; 15; 48). Other disadvantages noted ranged from loss of transactions during power failures to the increased cost of computer time (7; 16).

There were very limited comments in the replies received concerning problems with implementation and operation of bar coding systems. General comments concerning typical start-up problems were mentioned. One user stated that they had a problem with labels adhering to pallets, but the problem was resolved by double labeling all pallets (19).

Of the manufacturers and users responding, there is clear evidence that they feel bar coding is beneficial. Increased accuracy accompanied by reductions in manpower, cost, and time expended can be expected. There was not a single user that indicated dissatisfaction with the bar code system being used. The only comments from users that were not positive involved minor problems with start-up which could be expected with any major system implementation.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This chapter addresses the three research questions posed in Chapter I in a discussion and conclusion format. It also provides areas that warrant further investigation.

Discussion and Conclusions

Research Question 1

Why has the Air Force not made extensive use of bar coding technology?

Discussion. As noted in Chapter I, the Assistant Secretary of Defense (Installations and Logistics) directed the establishment of a Joint Steering Group to study Logistics Applications of Automated Marking and Reading Symbols (LOGMARS). The Air Force point of contact at the Air Staff level for this effort is LGXY. This office monitors Air Force logistics applications of bar code technology and interfaces closely with the Air Force Logistics Management Center (AFLMC) at Gunter AFS, Alabama. AFLMC/LGY is responsible for conducting a portion of the LOGMARS study. This portion of the study involves an evaluation of candidate symbologies and their functional applications. Conversations with these representatives, and with others

involved in bar code test programs, indicate that although the Air Force has not widely applied bar code technology, they are actively pursuing plans and programs to implement these systems. The results of these efforts will begin to be implemented some time after the completion of the LOGMARS study (11; 30; 34).

Conclusions. Bar code technology is not expected to be widely applied within the Air Force (and the military in general) until the results of the LOGMARS study have been distributed. Further, each intended application must also be subjected to an individual cost/benefit analysis before serious consideration will likely be given.

Research Question 2

What type of bar code symbols, equipment, and applications are available from industry, and what general and/or specific areas are amenable to bar code system application within the Air Force?

Discussion. It is apparent that a wide range of bar code symbols and equipment is available from industry. Further, tremendous flexibility in applying these systems seems to be possible. Based upon the data collected from manufacturers and users the general characteristics of candidate bar code applications were defined by the authors as the following:

1. Repetitive operations
2. High volume
3. High accuracy required
4. Time constrained operation
5. Boring operation for human
6. Current status required

Using these characteristics as guidelines and examining the data collected and literature reviewed, a list of potential applications was developed. These suggested uses are not exhaustive nor were they fully analyzed on an individual basis. As indicated previously, such an analysis would involve an extensive cost/benefit analysis for each application. They are merely provided as a starting point for future amplification and investigation. The candidate applications are roughly divided into depot applications, base level applications, and other applications.

Depot Applications. The following potential applications would be applicable to depot level organizations.

1. Tracking reparable items through the repair cycle
2. Sortation control systems used to control the flow of parts, components, assemblies through the depot
3. Warehouse automation and inventory control
4. Automatic generation of shipping documentation
5. Configuration control of major or complex reparables
6. Receiving and shipping function to provide inventory update, an in-motion Quality Control "inspection," and inventory sortation
7. Bench stock surveys

Base Level Applications. The following potential applications would be applicable at base level.

1. Supply--receiving function to provide inventory update, in-motion Quality Control, and sortation

2. Supply--Due in from Maintenance Control (DIFM) via a status code book and pen scanner for current status of equipment

3. Supply--Serialized Control and Reporting System (SCARS) to provide a rapid means to collect and then transmit status of serial controlled components to Item Managers on a daily basis

4. Supply--Document Control Section application to update document control records (DD Form 1348-1)

5. Supply--physical verification inventories

6. Supply--bench stock inventories via pen scanners

7. Maintenance--job control, "realtime" equipment status by tail number or complex number. Status book with bar codes and tail numbers, complex numbers could be used with pen scanner for data entry

8. Hospital--inventory control of drugs and supplies

9. Hospital--medical record and x-ray folder control system

10. Hospital--blood bag and sample control

11. Hospital--laboratory specimen control

12. Hospital--drug room access control via differentiated optics lock card

13. Hospital--medication schedule operation

14. Hospital--automatic billing system

15. Security--access control systems using differentiated optics

16. Security--main gate or parking gate activation systems

17. Aeriel Port--baggage control and sortation system

18. Aeriel Port--vehicle movement into and out of port

19. Equipment Custodians--physical inventories of accountable equipment

20. Base Service Store--point-of-sales system and inventory control of office supplies

21. Base Exchange--point-of-sale system and inventory control of tagged merchandise

22. Commissaries--point-of-sale system and inventory control of UPC-coded items

Other Applications. The following potential applications would be applicable for the area noted.

1. Large library circulation control (e.g., Air University Library)

2. Extension course material control and processing (e.g., Extension Course Institute)

3. Receiving and issue functions for large basic issue facilities (e.g., Air Force basic clothing issue at Lackland AFB, Texas)

4. Added to major weapon system contract requirements for equipment configuration control function

5. Use on club cards, Base Exchange, and Commissary credit card systems

As demonstrated above, there is a wide variety of applications recommended for further analysis. More intimate familiarity with various functional areas would undoubtedly surface many other equally suited or better

applications for bar code systems. It is important to note, however, that cost did not seem to be an overwhelming criteria for applying this technology in the civilian sector. In fact, 85.7 percent of the manufacturers that responded failed to even comment upon the cost savings associated with these systems. Sixty-eight percent of the users similarly indicated either no significant change in cost or failed to comment at all on this factor.

Within DOD cost is obviously an important factor. Recent and potential budget constraints have and will continue to focus attention on the cost effectiveness of all new acquisitions. Hence, it is reasonable to assume that bar code systems will be applied where their benefits justify the capital investment and operation costs of these systems. Other benefits, although they contribute substantially to increased effectiveness and efficiency, may be overshadowed by the cost factor. That consideration should be paramount in any analysis of bar code applications within the Air Force if the recommendation is likely to be accepted.

Conclusion. A wide range of bar codes, equipment, and applications are available from industry and it is believed that this technology can be applied successfuly to a variety of Air Force activities. These applications range from standard logistics functions to hospital, security, library,

and administrative functions. Although cost does not seem to be a major determinant of bar code technology application within industry, significant attention must be focused on this factor in any Air Force analysis of bar code applications due to current and probable future budget constraints.

Research Question 3

What are some of the problems associated with implementing bar code technology in Air Force activities?

Discussion. The approach taken here was to determine what problems had been encountered by industry and then determine whether or not similar problems could be anticipated by Air Force activities. The responses received from manufacturers and users failed to indicate any significant problems or trends encountered with bar code systems. Aside from vague descriptions of initial start-up difficulties (as would be expected for all new systems) only one response directly addressed operational problems associated with the use of bar code equipment. One user, the Federal Reserve Bank of Boston, did report a label problem that focused on a defective adhesive backing. Problems arose when labels occasionally fell off the containers used to transport currency to and from the bank vault. The problem was resolved by double labeling each container (19). No other specifically identified problems were noted.

Conclusion. Because there was a conspicuous absence of operational problems noted by the users contacted, it is concluded that few problems should be encountered in the application of bar code equipment to Air Force activities. The only possible exception might be those applications which require a radical departure from the current equipment configurations, bar code symbologies, or applications available. Applications in hostile and physically demanding environments, however, could entail considerable problems that industry has not been required to deal with. It is emphasized, however, that sufficient data to firmly support these contentions was not collected during this research.

Suggested Areas for Further Research

Based upon the research findings and conclusions enumerated above, the researchers feel that there are several specific areas where additional investigation could be advantageous. Since this research effort was not an attempt to provide an in-depth analysis of any one area, but rather to present a wide and diverse survey of the applicability of bar coding technology, a more general theme was pursued. In order to more fully define the characteristics, advantages, and disadvantages of bar code systems, the following areas should be studied further.

1. Applications to documents and forms
2. Uses in management information systems

3. Uses in war-time environments

4. Additional uses at base, depot, or other levels

In addition to these areas, a specific determination of the optimal type of equipment, code symbol, and labels for each particular application should be determined, and a thorough cost/benefit analysis completed. Other areas that should be pursued are the alternative types of automatic reading technologies such as: Optical Character Recognition (OCR), electromagnetic devices, and magnetic bar codes. These technologies should be investigated to determine whether or not they would be more appropriate than optical bar coding for military applications in general or for specific applications.

APPENDICES

AD-A060 771   AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCHO--ETC   F/G 9/4
A SURVEY OF OPTICAL BAR CODE TECHNOLOGY APPLICABLE TO AIR FORCE--ETC(U)
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APPENDIX A

DEFINITION OF TERMS

For the purpose of this study the following terms are defined as indicated.

Bar Code--array of rectangular marks and spaces in a predetermined pattern depicting machine language information.

Cathode Ray Unit (CRT)--a device that has a keyboard and television-like screen that allows the operator to make input to and receive output from a central computer.

Decoder--a unit used in a bar code scanning system. The decoder interprets the electrical signals from the scanner and provides the information to a central processor or peripheral equipment in a useable format.

Depth-of-Field--the distance over which a label being scanned will remain in focus. This is not the same as the distance from the label to the scanner.

Differential Optics--a technique for making bar codes on plastic identification cards invisible to the eye. Coding is accomplished with optical filters that are part of the plastic card itself. The filters are invisible and inaccessible.

Fixed Beam Scanner--a code reader using a stationary beam or beams to read and identify bar codes.

Incandescent Lamp--a lamp in which the light is produced by a filament of conducting material contained

in a vacuum and heated to incandescence by an electric current.

Label Printer Applicator--a type of impact printer with an applicator device; automatically prints, bursts, glues, and applies paper labels.

Logistics Applications of Marking and Reading System (LOGMARS)--name applied to the DOD Joint Steering Group appointed by the Assistant Secretary of Defense (Installations and Logistics) to study Logistics Application of Automated Marking and Reading Symbols. The group is composed of members from the Services and Defense Logistics Agency.

Moving Beam Scanner--a code reader that actively searches for code marks by sweeping a moving beam through a field of view.

Multiplexer--a device that can be used in a bar code system to interface the output of several scanners simultaneously with a host computer.

Photosensor--a photo-sensitive electric device incorporated in an electric circuit and used in controlling mechanical devices; also referred to as an electric eye or photocell.

Point-of-Sales--a system that records sales and adjusts inventories at the time of the sale by reading a code affixed to the item being sold.

Print Contrast Ratio--a term used to measure the reflectance contrast between the printed character or mark and its background. Insufficient contrast could result in a scanner failing to read a symbol properly.

Printability Gage--a printing pattern used by printers to evaluate the size and quality of label that can be printed using a particular combination of equipment, label surface material, ink, and the direction and speed of the labels through the printer. This gage can also be used for quality control.

Reflective Scanner--a type of fixed beam scanner that employs two sets of optics, one to illuminate a label and another to collect the reflected light from the label.

Reflex Scanner--a type of fixed beam scanner that employs a single set of optics for illumination of a label and collection of the reflected light. Two versions are used, the one-way mirror and coaxial. The difference between these versions lies primarily in the location of the photosensor used to collect the reflected light.

Retroflective--characteristic of material causing it to reflect light back to the source.

Speedex--System-wide Project for Electronic Equipment at Depots, Extended; the automated, integrated, standardized automatic data processing system used by Army Materiel Command (AMC) depots.

Universal Product Code (UPC)--bar code developed by the grocery industry to uniquely identify manufacturers and their products.

Verifier--a device that operates essentially the same as a hand-held scanner but is used solely to verify that a particular label is scannable and contains the right information.

APPENDIX B

ENCODING DATA INTO BAR CODE LABELS

Bar Code Symbols

The information summarized in this appendix was obtained from references 4 and 38. As indicated in Chapter I of this thesis, there are many bar code symbols that have been developed for various specific and general applications. The basic mechanics of how these symbols are read by scanners was discussed in Chapter I. How information is initially encoded into the label is the subject of the succeeding paragraphs. Additionally, some of the more prominent bar codes are described and illustrated.

In general, each code employs some specific pattern of bars and spaces to represent each desired character. The number of bars and spaces employed varies from code to code. Additionally, the sequence of bars and spaces determines which character is being represented. In order to illustrate how one symbol encodes both alphabetic and numeric data, the popular Code 39 will be examined.

Code 39 (or 3 of 9) is a full alphanumeric bar code with special characters. This code uses both bar and space, width and sequence to encode data. Figure 3 will be used to examine how data is encoded in this symbology.

Each character consists of 5 dark bars (two wide) and 4 light spaces (only one can be wide). Hence the name 3 of 9 (9 bars and spaces per character, but only 3 are

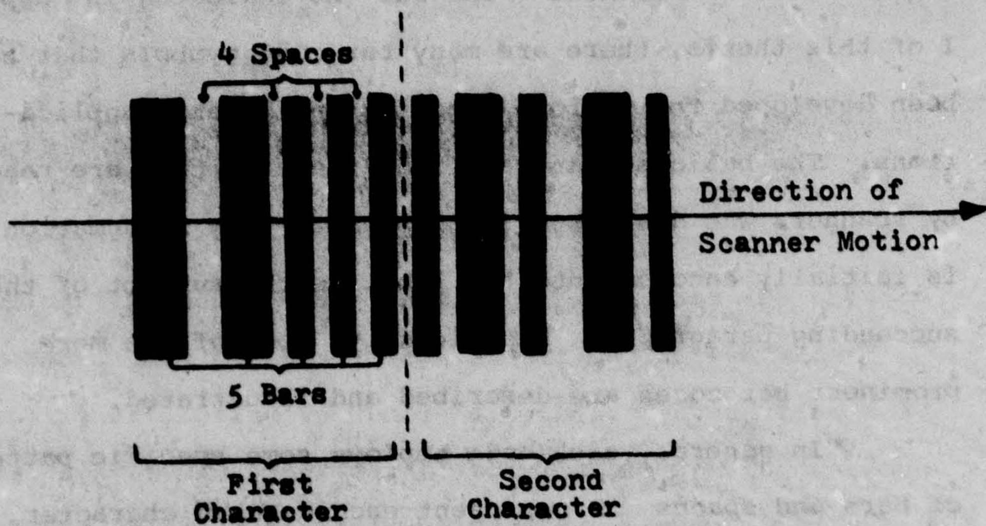

Fig. 3. Sample Code 39 Characte[illegible]

used to define the character). Wide bars and space[illegible] designated a "one" and narrow bars and spaces are "zero." The first character in the above figure would then be 11000 (bars) and 1000 (spaces). This information must then be decoded to arrive at the desired character. Referring to Figure 4 (the decoder portion of a scanner does this automatically), the above code equates to a "W". In a similar fashion, the second character decodes to 01010 and 0010 which equates to "I".

This particular code offers a great deal of flexibility that many codes do not because of its alphanumeric

CHAR.	BARS	SPACES	CHAR.	BARS	SPACES
1	10001	0100	K	10001	0001
2	01001	0100	L	01001	0001
3	11000	0100	M	11000	0001
4	00101	0100	N	00101	0001
5	10100	0100	O	10100	0001
6	01100	0100	P	01100	0001
7	00011	0100	Q	00011	0001
8	10010	0100	R	10010	0001
9	01010	0100	S	01010	0001
0	00110	0100	T	00110	0001
A	10001	0010	U	10001	1000
B	01001	0010	V	01001	1000
C	11000	0010	W	11000	1000
D	00101	0010	X	00101	1000
E	10100	0010	Y	10100	1000
F	01100	0010	Z	01100	1000
G	00011	0010	-	00011	1000
H	10010	0010	.	10010	1000
I	01010	0010			
J	00110	0010			

Fig. 4. Code 39 Character Equivalence [38]

capability. Another code which also exploits the added information capacity provided by the spaces between the bars is the interleaved two-of-five code. This code is numeric only and uses the added capacity to encode more numbers in the same size label.

In addition to the normal character capability of each code, most codes employ various start and stop patterns to tell the scanner when the label begins and ends. Also parity checks and direction of scan bars are not uncommon. All of these marks should be ignored when visually attempting to decode a symbol. In addition to bars, spaces and other marks, most labels include various versions of human readable characters. It is important to note that these characters may or may not be lined up exactly with their bar/space equivalent. In general, then, in order to properly decode a particular symbol one needs to know what pattern of bars and spaces make up a character, which patterns to ignore, and how to correlate it with other data provided on the symbol.

The codes shown in Figure 5 are in wide use today and warrant a brief description. Other codes that are in use but are not as widely distributed are the Binary, Binary Coded Decimal, Periodic Binary, Bi-level, Geometric, Panacode, EAN, AMES, MSI, Mixodorf, AGES, DREF, MRC, and Code 11.

CODES	DESCRIPTION
Bull's Eye	An array of concentric set of rings and spaces in a pattern to define various characters. This code is omnidirectional and is used in various industrial sortation systems where items tend to be randomly oriented on a conveyor.
CODABAR a1234567890t	A format in which 4 bars and 5 intervening spaces are used to represent the digits 0-9 and certain alpha and special characters. Used in libraries, hospitals, industrial, and retail applications.
Decimal	A code in which one uniquely shaped code bar represents each decimal digit. Used in railroad industry to label cars and in other industrial applications.
Distribution (DC) 312345 67890	An eleven-digit code that is compatible with the UPC. Used in warehousing operations, especially on corrugated cartons.

CODES	DESCRIPTION
Interleaved Two-of-Five (i 2 of 5) 12345678	A modified version of the Two-of-Five code which uses spaces as well as bars to encode the decimal digits. Used primarily in industrial applications.
Pulse Width Modulated (PWM) 017 98765 43214	A code which uses a bar width plus space width combination to define a bit. For example, a wide bar followed by a narrow space is a "1", while a narrow bar followed by a wide space is a "0". Various combinations of bits are then combined to define desired characters. This code is used in libraries (Plessey Code is a PWM code) and various industrial uses.
Three-of-Nine (Code 39) *AXZ15499866N*	A code in which a combination of three out of nine bits represent the digits 0-9, a 26-character alpha set, and special characters. Used for inventory control, libraries, retail, and industrial applications.

CODES	DESCRIPTION
Two-of-Five (2 of 5) 1234567	A code in which a combination of two bits out of five define the digits 0-9. Used primarily in industrial applications.
Universal Product Code (UPC) 0 12345 67890	A ten-digit code adopted by the grocery industry which identifies the product (first 5 digits) and the manufacturer (second 5 digits). It can be read in either direction. Used on grocery products, periodicals sold through checkout stands, and other point-of-sale applications.

Fig. 5. Example of Widely Used Bar Codes

APPENDIX C

LIST OF BAR CODE EQUIPMENT MANUFACTURERS AND USERS CONTACTED

Manufacturers

1. ACI Corporation
   Chicago, Illinois

2. Accu-Sort Systems, Incorporated
   Sellersville, Pennsylvania

3. Avery International, Incorporated
   San Marino, California

4. Automatic Parking Devices, Incorporated
   Farmington, Michigan

5. Bendix Recognition Systems
   Southfield, Michigan

6. Burroughs Corporation
   Detroit, Michigan

7. Checkpoint Systems, Incorporated
   Barrington, New Jersey

8. Computer Identics Corporation
   Westwood, Massachusetts

9. Control Data Systems, Incorporated
   Minneapolis, Minnesota

10. Data General Corporation
    Southborough, Massachusetts

11. Data Terminal Systems, Incorporated
    Maynard, Massachusetts

12. Dennison Manufacturing Company
    Farmington, Massachusetts

13. Fasson
    Painesville, Ohio

14. General Scanning, Incorporated
    Watertown, Massachusetts

15. Gottscho, Adolph, Incorporated
    Union, New Jersey

16. Gould, Incorporated
Rolling Meadows, Illinois

17. Hobart Corporation
Troy, Ohio

18. Honeywell, Incorporated
Minneapolis, Minnesota

19. Identicon Corporation
Waltham, Massachusetts

20. Interface Mechanisms, Incorporated
Mountlake Terrace, Washington

21. International Business Machines Corporation
Armonk, New York

22. MRC Corporation
Hunt Valley, Maryland

23. MSI Data Corporation
Santa Fe Springs, California

24. Markem Corporation
Keene, New Hampshire

25. McKontrol, Incorporated
Northboro, Massachusetts

26. Metrologic Instruments, Incorporated
Bellmawr, New Jersey

27. Monarch Marking System
Dayton, Ohio

28. National Cash Register
Dayton, Ohio

29. National Semi-Conductor Corporation
Santa Clara, California

30. Optical Scanning Corporation
Newtown, Pennsylvania

31. Optronics International, Incorporated
Chelmsford, Massachusetts

32. Recognition Equipment, Incorporated
Irving, Texas

33. Rexnord, Incorporated
Milwaukee, Wisconsin

34. Rockwell International
Pittsburgh, Pennsylvania

35. Spectra Graphics
Ashland, Massachusetts

36. Sperry Rand Corporation
New York, New York

37. Sweda International
Pinebrook, New Jersey

38. Sylvania Corporation
Waltham, Massachusetts

39. Teledyne Systems Company
Rosslyn, Virginia

40. Weber Marking Systems
Arlington Heights, Illinois

41. 3M Company
Saint Paul, Minnesota

Users

1. Air Force Academy Library
Colorado Springs, Colorado

2. Air Training Command
San Antonio, Texas

3. Alvey, Incorporated
Saint Louis, Missouri

4. American Distilling Company
New York, New York

5. American Tobacco, Incorporated
New York, New York

6. Bayer, A. J.
Shepherdsville, Kentucky

7. Buick Motor Division
Flint, Michigan

8. Buschman, E. W.
Cincinnati, Ohio

9. Carter-Wallace, Incorporated
New York, New York

10. Chevrolet Motor Division
Lansing, Michigan

11. Chrysler Corporation
Detroit, Michigan

12. Colgate-Palmolive Corporation
Jersey City, New Jersey

13. Commissary Sales Store
Norfolk, Virginia

14. Conveyor Systems, Incorporated
Morton Grove, Illinois

15. Crown Zellerback Corporation
San Francisco, California

16. Dunham, S. P. Company
Trenton, New Jersey

17. Dupont, E. I. Company
Wilmington, Delaware

18. Eagle Rubber Company
Ashland, Ohio

19. Eastern Airlines
New York, New York

20. Federal Reserve Bank
Washington, D.C.

21. Fiber Industries
Salesbury, North Carolina

22. Fort Howard Paper Company
Green Bay, Wisconsin

23. Frigid Meats, Incorporated
Chicago, Illinois

24. Hoffman-Laroche, Incorporated
Nutley, New Jersey

25. Iowa Beef
Amarillo, Texas

26. Kimberly Clark
Neeah, Wisconsin

27. Milwaukee Public Library
Milwaukee, Wisconsin

28. Pabst Brewing Company
Milwaukee, Wisconsin

29. Phillip Morris
New York, New York

30. Polaroid Corporation
Cambridge, Massachusetts

31. Pontiac Motor Division
Pontiac, Michigan

32. RCA Record Division
New York, New York

33. Rauland Division
Melrose Park, Illinois

34. Remington Arms
Ilion, New York

35. Reynolds, R. J.
Winston-Salem, North Carolina

36. Riverside Hospital
Columbus, Ohio

37. Rust-Oleum Corporation
Haggerstown, Maryland

38. Scott Paper Company
Philadelphia, Pennsylvania

39. Seagrams and Sons, Limited
New York, New York

40. Shell Oil
Houston, Texas

41. TRW, Incorporated
Cleveland, Ohio

42. Texas University Library
Austin, Texas

43. Thom McAn
Brockton, Massachusetts

44. Toledo Scale
Columbus, Ohio

45. United States Nuclear Regulator Agency
Washington, D.C.

46. Villanova University Library
Villanova, Pennsylvania

47. Wella Corporation
Englewood, New Jersey

48. Winthrop Laboratories
New York, New York

49. Wright Machinery Company
Durham, North Carolina

APPENDIX D

EXAMPLES OF LETTERS FORWARDED TO BAR CODE EQUIPMENT MANUFACTURERS AND USERS

Dear Sir,

We are currently involved in completing a master's thesis as partial fulfillment for a Master of Science degree in Logistics Management from the Air Force Institute of Technology at Wright-Patterson Air Force Base, Ohio. The subject of our research is "Application of Optical Bar Coding Systems to Air Force Activities."

We have become aware that you are currently using a type of bar code equipment (reference the attached material). We are highly interested in obtaining more information regarding your application of this equipment. The following information is desired:

a. Specific application?
b. Cost savings?
c. Manpower savings?
d. Time savings?
e. Accuracy improvements?
f. Personnel resist new system?
g. Reliability?
h. Other advantages?
i. Disadvantages?

If you are no longer using this system please explain why (e.g., problems encountered, etc.).

We realize that it may not be possible to answer all the questions listed above; however, your cooperation in providing as much information as practical will be greatly appreciated.

This is not an official Air Force request for information, but any information your company can provide will be used in the thesis research. <u>Please indicate</u> in your reply whether your company name may be used in the thesis.

Please forward your reply to the following address at the earliest possible date:

Air Force Institute of Technology
School of Systems and Logistics
Attn: Capts. Wilderman and Windham/78B
Wright-Patterson Air Force Base, Ohio 45433

Thank you for your assistance in this research effort.

Michael B. Wilderman — Captain, USAF

Thomas D. Windham — Captain, USAF

Dear Sir,

We are currently involved in completing a master's thesis as partial fulfillment for a Master of Science degree in Logistics Management from the Air Force Institute of Technology at Wright-Patterson Air Force Base. The subject of our research is "Applications of Optical Bar Coding to Air Force Activities." In order to evaluate potential applications of this technology it is important that we obtain current information regarding present and, where possible, projected bar code equipment and systems.

We are aware of your involvement in bar code systems and would appreciate any assistance which you could provide. The specific types of data requested are listed below. Please disregard any items that are not applicable to your product.

a. Hardware description and specifications (illustrations and or brochures would be appreciated),

b. Hardware price,

c. Estimated implementation cost,

d. Estimated operation cost,

e. Estimated cost savings,

f. Does the equipment reduce manpower requirements?

g. Does the equipment reduce processing time requirements?

h. Would you expect an improvement in processing accuracy?

i. Please provide any other advantages of your equipment.

In addition to the above information we would like to obtain the names and addresses of several of the companies who are using your equipment. This information is needed in order to investigate the specific applications of your equipment.

Please do not construe this inquiry to be an official Air Force Request for Proposal or Invitation to Bid for bar code

hardware. This is an independent study that is directed at providing information and background research for other potential DOD researchers. Please indicate in your reply whether your company name may be used in the thesis.

Please forward your response to the following address as soon as possible.

Air Force Institute of Technology
School of Systems and Logistics
ATTN: Capts. Wilderman and Windham/78B
Wright-Patterson Air Force Base, Ohio 45433

Because of the time constraints placed on our effort, we would appreciate a response prior to May 25, 1978. Thank you for your assistance in this research effort.

Michael B. Wilderman
Captain, USAF

Thomas D. Windham
Captain, USAF

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